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REPORT R-1645

UNITED STATES ARMY MUNITIONS COMMAND

FRANKFORD ARSENAL

DEVELOPMENT OF RELEASE BOLT, NONFRAGMENTATION

by

R. C. SUTTER

Report R-1645

OMS Code 5110.22.011
DA Project 5S02-06-001

June 1962

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Prepared by: R. C. Sutter
R. C. SUTTER
Engineering Technician

Reviewed by: R. F. LeVino
R. F. LeVINO
Acting Chief
Propellant Actuated Devices Division

Approved by: C C Fawcett
C. C. FAWCETT
Acting Chief
Research and Development Group
Pitman-Dunn Laboratories

For:

C. W. EIFLER
Colonel, Ordnance Corps
Commanding

FRANKFORD ARSENAL
Research and Development Group, Pitman-Dunn Laboratories
Philadelphia 37, Pa.

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ABSTRACT

When fired, explosive bolts currently present the danger of flying fragments from the bolt. A project was initiated to develop a nonfragmentation bolt to replace the common explosive bolt. Specifications for the explosive bolt on the clamp ring of Project Mercury were used as a guide.

The design selected for development was one that utilized two shear pins as retention members on the bolt. By changing the materials and hardness of these pins, release bolts of many different strengths could be developed. The basic design utilized T14E2 ignition elements as the source of propellent gas for separation of the bolt.

The release bolt developed (Design C) offers the prime advantage of separating without external fragmentation. This design is flexible and can be applied to standard cap screw designs. It can be used in place of most existing types of explosive bolts. Further, the electric ignition element can be modified to incorporate necessary additional propellant charge to reduce the complexity of the design as it now stands.

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INTRODUCTION

As used in aircraft, space capsules, and missiles, explosive bolts present the danger of flying fragments from the bolts when fired. At the request of the Industrial Division of Frankford Arsenal, a project was initiated to develop a nonfragmenting bolt to replace common explosive bolts.

As a guide in this development, National Aeronautics and Space Administration (NASA) specifications for the explosive bolt on the clamp ring of Project Mercury were used.

DESIGN NOTES

Several design concepts for a nonfragmenting release bolt were studied. The design selected for development was one that utilized two shear pins as retention members on the bolt. By changing the materials and hardness of these shear pins, release bolts of many different strengths could be developed. The basic design utilized two T14E2 ignition elements as the source of propellent gas for separation of the bolt.

Design A

Design Aspects

Design A, shown in Figure 1, operates as follows. The T14E2 ignition element is initiated using a battery with an output of at least two amperes or a suitable impulse generator. Gas from either ignition element will flow through the vent hole in the bolt and ignite the other ignition element. Gas produced from these

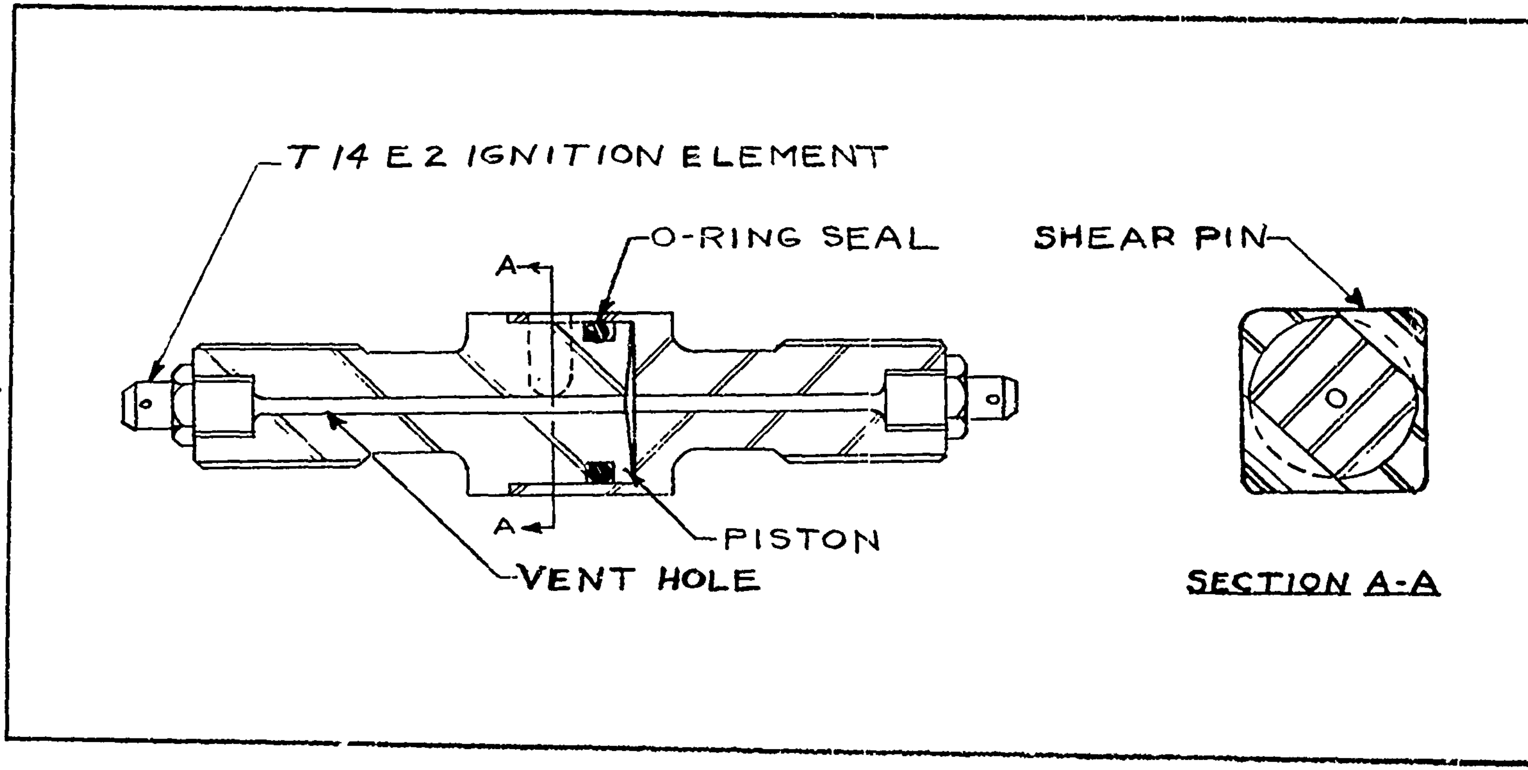

Figure 1. Release Bolt, Design A

ignition elements acts on the piston area. When this pressure exceeds the shear strength of the shear pins, the piston moves, shearing the pins and permitting separation of the bolt. Three release bolts were fabricated and assembled using 2024-T4 aluminum shear pins.

Mechanical Tests

Tensile tests were conducted on all the release bolts fabricated in this program. Results of these tests are shown in Appendix A. On the initial release bolts, the skirt of the bolt failed under a tensile load of 9000 pounds. To overcome this, magnesium shear pins were used in place of the 2024-T4 aluminum pins. Tests were then conducted and the magnesium pins sheared at 5880 pounds, well below the fail strength of the bolt skirt, as desired.

Firing Tests

The first firing tests were conducted on the release bolt to determine and confirm the correct size of the gas vent through the center of the bolt. On the initial design this hole size was held to a minimum in order to maintain a small initial volume. To check the hole size, T14E2 ignition elements were fired in one section of the bolt. The gas flow proved adequate and no failures of the ignition element occurred. This indicated that the pressure build-up was not excessive.

The release bolts were now assembled with magnesium shear pins and one ignition element to determine if one ignition element produced enough energy to shear the pins. Two tests were conducted with unsuccessful results. On the third test a T14E2 special ignition element with a conductive mix and one grain of ball propellant was used. Use of the conductive mix eliminated the need for bridge wires (used in the standard ignition element); however, much more electrical energy is required to fire the element. Successful operation was obtained using this special ignition element.

These firing tests were conducted with the bolt clamped in a horizontal position. A wooden box containing waste was used in order to recover the bolt after separation.

Design B

Design Aspects

In order to meet the desired tensile strength of 14,000 pounds, the release bolt was redesigned to withstand forces in excess of 20,000 pounds. Two simple changes were required to obtain this additional strength:

(1) The skirt on the chamber was extended 1/4 inch, thus removing the square on the piston;

(2) The piston diameter was decreased from 1 inch to 7/8 inch. Six bolts of this design were fabricated.

Mechanical Tests

Tensile tests were conducted on three of the bolts, using 2024-T4 aluminum alloy shear pins. Results, shown in Appendix A, were satisfactory.

Firing Tests

Firing tests were conducted with the release bolt held in a vertical position and the chamber section threaded into a steel plate. A water trap was used to recover the bolt after separation and prevent it from being damaged.

Using two standard T14E2 ignition elements as the energy source, a test was conducted to determine if the desired fail operation would result. This test was not successful; the

standard ignition elements lacked sufficient energy to shear the 2024-T4 aluminum pins. The pressure required to shear the pins, using a shearing force of 13,500 pounds, is

$$P = \frac{F}{A} = \frac{13,500}{0.601} = 22,400 \text{ psi}$$

where P = psi to shear pins

A = area of piston

F = force required to shear pins.

In the next test, two special T14E2 ignition elements were used, each containing a conductive mix with a grain of ball type propellant. In this test, satisfactory bolt separation was obtained as designed; however, the sheared segments of the shear pin were not retained in the piston end of the bolt.

In subsequent tests conducted on the bolts of this design, high speed motion pictures were taken and the sheared segments of the pin were recorded and observed. It was concluded that although the sheared segments of the pin left the piston with low velocity, this condition was not desirable.

Several attempts were made to retain the sheared segments in the piston. The first attempt was made using an adhesive on the shear pin. Several different adhesives were tried, none of which were successful.

When this approach failed, a groove was cut into the shear pin bearing surface of the piston, to enable the shear pin segment to key itself to the piston at separation. This approach was also not successful.

At this time a study of the results of all the tests conducted on the Design B release bolt revealed three areas that required improvement:

(1) The sheared segments of the shear pin must be retained.

(2) The bolt strength was approximately 1000 pounds below that desired.

(3) A battery is required for initiation with the special ignition element containing the conductive mix. It was believed that the use of a hand impulse generator would be more desirable and this, in turn, meant going back to the bridge wire igniter.

Design C

Design Aspects

To retain the sheared segments in the piston and, also, to increase the shearing area of the shear pin, one design change was required. This change was accomplished by moving the shear pins radially toward the axis of the bolt (as shown in Figure 2), thereby keying the sheared segment of the pin into the piston at the time of separation. Moving the pins toward the bolt axis also increased the shearing area of the pins.

The energy of the standard T14E2 ignition element was supplemented with three grains of ball propellant loaded in a caliber .22 rim fire cartridge case. To accomplish this, a small aluminum sleeve, one-eighth of an inch shorter than the case, was slipped over the case mouth. This assembly was then inserted into the end of the ignition element and the entire assembly was dipped into epoxy resin for sealing. Figure 3 shows details of this modified ignition element.

Mechanical Tests

Three release bolts of this design were fabricated, and tensile tests were conducted using aluminum and brass shear pins. An average shear value of 15,150 pounds was obtained with the brass pins in the Design C bolt, whereas when used on the Design B bolt, an average shear value of only 11,900 pounds was obtained.

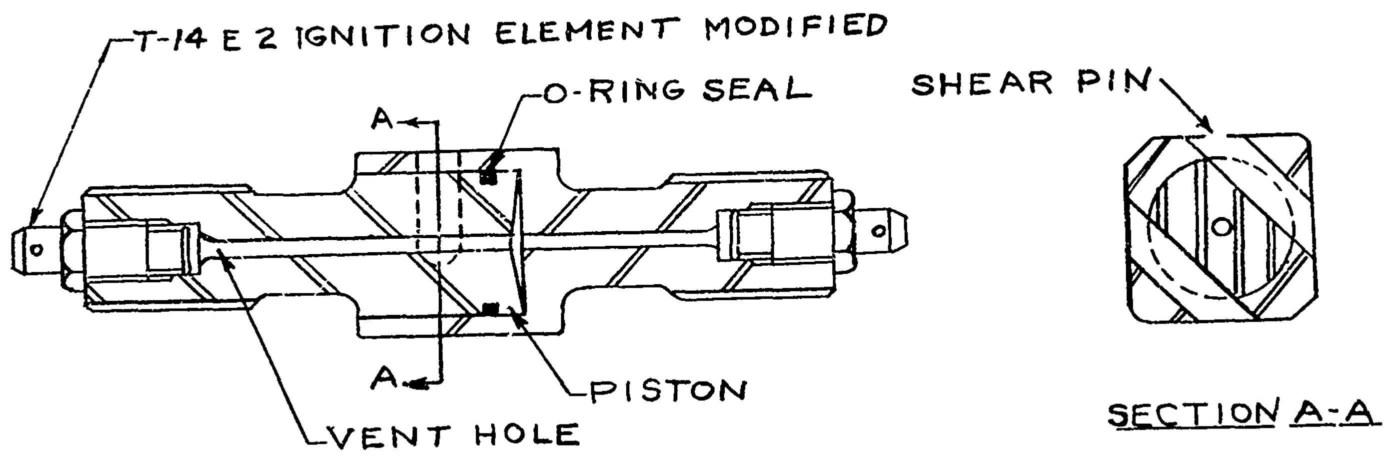

Figure 2. Release Bolt, Design C

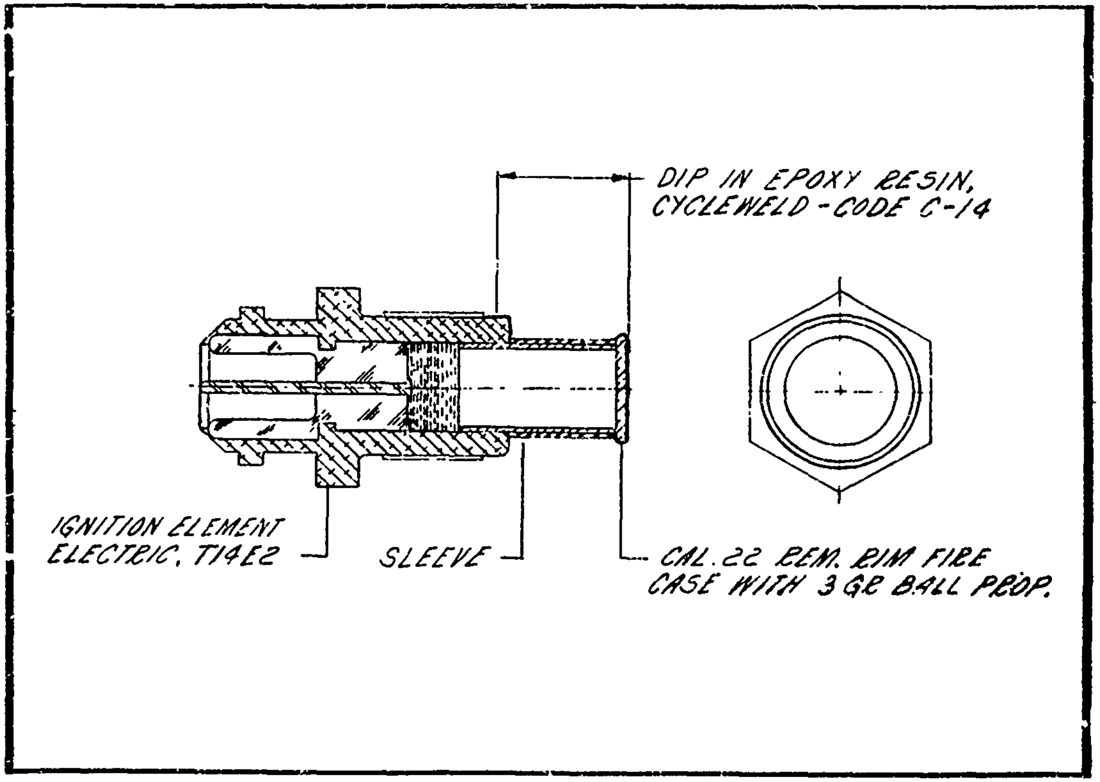

Figure 3. Modified T14E2 Ignition Element

In an attempt to determine the peak strength of the bolt, a fixture was designed and fabricated to conduct hydrostating tests on the bolt chamber. Using hardened dowel pins to prevent bolt separation, a pressure of 49,000 psi was reached when a leak was detected in the test fixture. The fixture was repaired and the test resumed. The leak reoccurred at 33,000 psi, at which time it was decided to pull the bolt on the tensile testing machine until failure. This occurred when a tensile load of 27,500 pounds was applied. As the bolt is designed for a maximum tensile load of 17,000 pounds, the margin of safety is sufficient.

To complete the testing on this program, six release bolts were used; three bolts of Design B, using aluminum pins, averaged 13,000 pounds shear, and three bolts of Design C, using brass pins, averaged 15,150 pounds shear.

Firing Tests

Using brass shear pins and the modified T14E2 ignition elements, seven firing tests were conducted. A hand impulse generator was used to fire the ignition elements. All tests were successful - in every test, both ignition elements fired and the sheared segments were retained in the piston part of the bolt. Subsequently, 40 tests were conducted with these same bolts over the temperature range of -65° to 160° F. The modified T14E2 ignition element was used in all these tests. The functioning time (interval between the application of energy to the ignition element and actual separation of the bolt segments) was measured.

GENERAL COMMENTS

Figure 4 is a wiring diagram for the test set up used to determine functioning time. The start pulse was a 135 volt charge from a storage battery. This pulse triggered two time interval meters and simultaneously fired the ignition elements. When the bolt separated, it closed the stop circuit, thereby stopping both timers. Two timers were used to check the validity of every result.

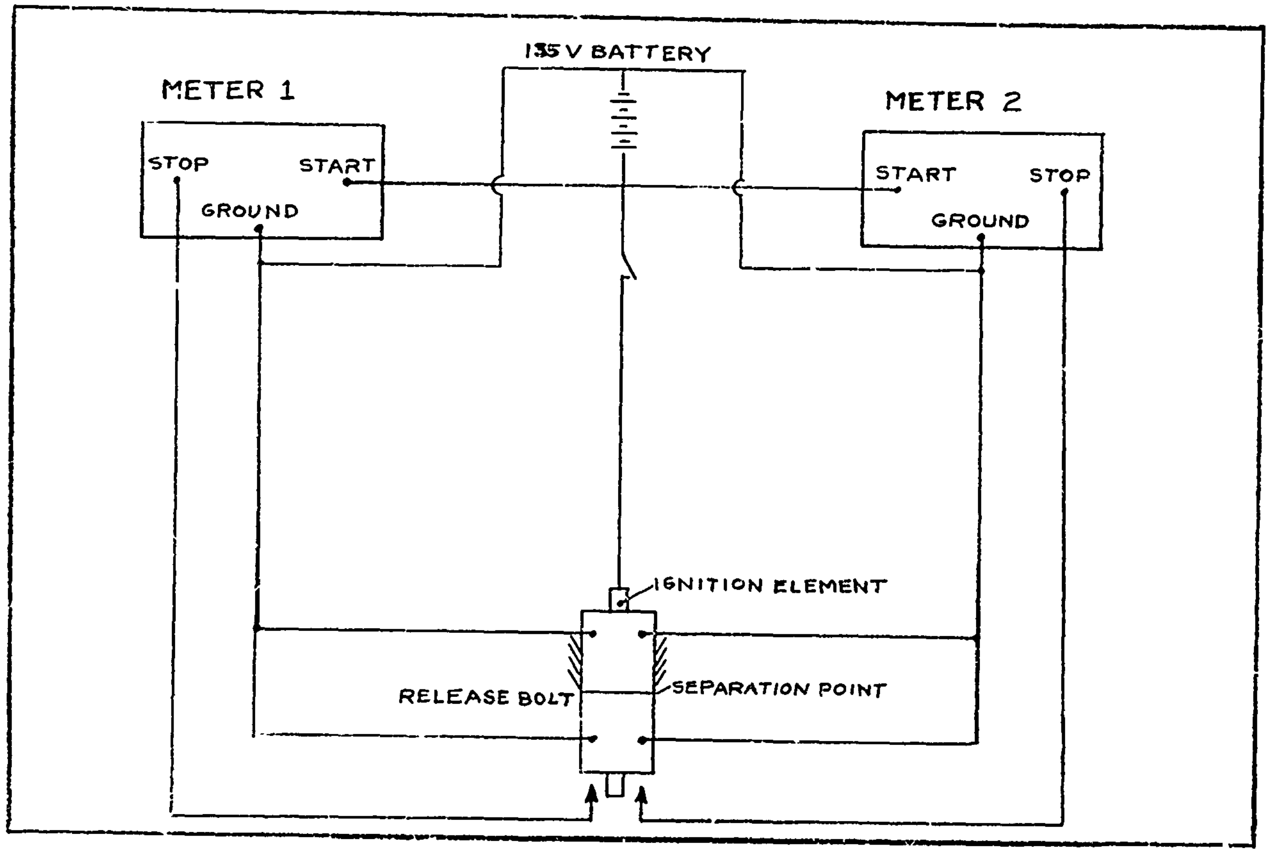

Figure 4. Wiring Diagram for Functioning Time Study of Release Bolts

Results indicate that the release bolts separate after 1.5 to 3.3 milliseconds, depending both upon ambient temperature and upon shear pin material. Bolts with aluminum pins performed with lower functioning times and less time spread than bolts with brass shear pins (Figure 5).

The range of functioning times for release bolts with both types of pin are summarized as follows.

Temperature (° F)	Release Bolt Functioning Time (ms) Aluminum Pin	Brass Pin
160	1.56 - 1.90	1.68 - 2.61
70	1.89 - 2.16	1.91 - 3.26
-65	2.13 - 2.49	1.64 - 3.12

A round by round record of these firings is presented in Appendix B.

It should be noted that on two tests, the bolt failed to separate. Careful examination after the tests revealed that on both failures, the ignition elements fired but the gas pressure in the bolt chamber was too low to shear the pins due to a damaged O-ring that had been used many times.

It should also be noted that all of the tests were conducted with no preload on the bolt. This is the most severe condition for testing, since all of the separation energy must be produced by the ignition elements. If a preload had been applied to the bolts, as would be the case under actual operating conditions, less additional energy would be required to effect bolt separation.

CONCLUSIONS

1. This release bolt (Design C) offers the prime advantage of separating without external fragmentation, thereby making it desirable, for example, for use in missile stage assemblies.

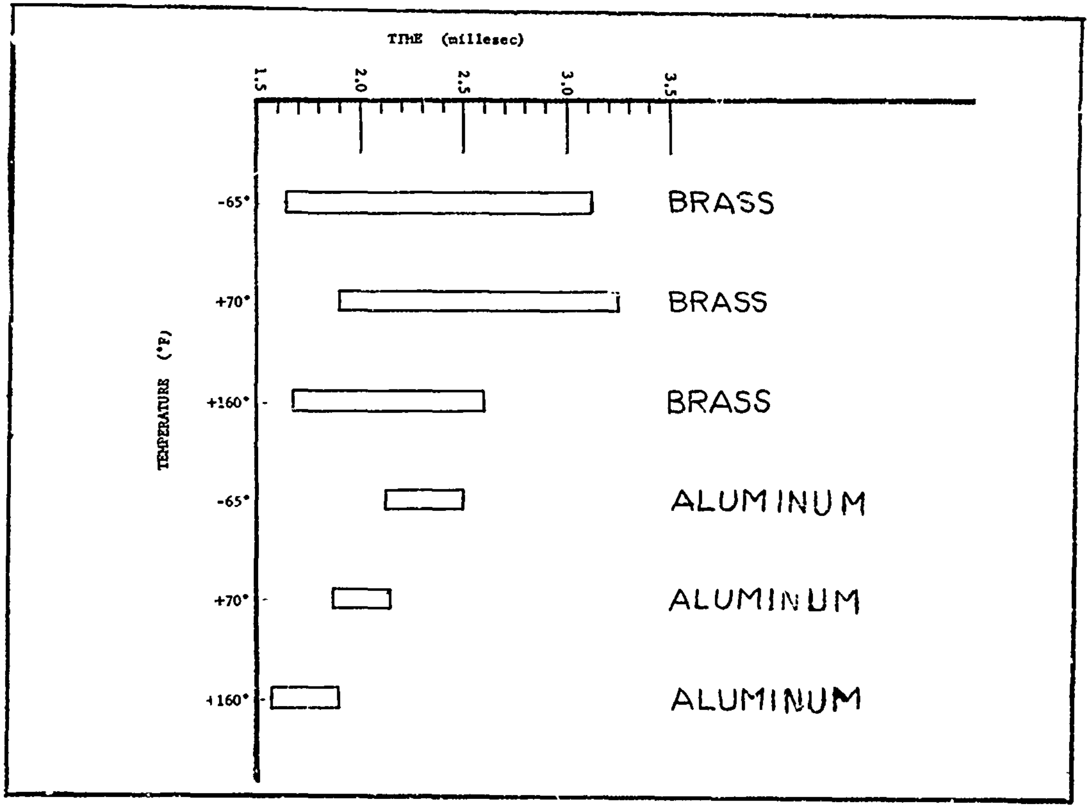

Figure 5. Functioning Time Range, Release Bolt

2. The release bolt (Design C) developed in this program can be used in place of most existing types of explosive bolts. This design is flexible and can be applied to standard cap screw designs.

3. It is further concluded that the electric ignition element presently used can be modified to incorporate the necessary additional propellant charge to reduce the complexity of the design as it now stands.

APPENDIX A

RELEASE BOLT
MECHANICAL LABORATORY TEST DATA

Tests to determine average shear stress on 0.250 inch diameter (0.049 sq in. clear area) shear pin material.

	Test No.	Force to Shear (lb)			Material
	1	2620			Bridgeport brass
	2	2640			Ditto
	3	2620			Ditto
	4	2580			Ditto
	5	2620			Ditto
	6	2570			Ditto
Total			15650		
Average			2608		
Shear force			$\frac{2608\text{ lb}}{0.049\text{ sq in.}}$	= 53,200 psi	
	1	2100			2024-T4 aluminum
	2	2075			Ditto
	3	2105			Ditto
	4	2135			Ditto
	5	2125			Ditto
	6	2140			Ditto
Total			12680		
Average			2113		
Shear force			$\frac{2113\text{ lb}}{0.049\text{ sq in.}}$	≅ 43,000 psi	
	1	2730			Anaconda brass
	2	2715			Ditto
	3	2715			Ditto
Total			8160		
Average			2720		
Shear force			$\frac{2720\text{ lb}}{0.049\text{ sq in.}}$	= 55,500 psi	

APPENDIX B

ROUND BY ROUND FIRING DATA

Round No.	Shear Pin	Temp (° F)	Time (ms)	Remarks
1	Brass	160	2.26	Cycled to -65° F; then to 160° F.
2	Brass	160	1.68	OK
3	Brass	160	2.51	OK
4	Brass	160	2.04	OK
5	Brass	160	2.62	OK
6	Brass	160	1.79	OK
7	Aluminum	160	1.86	OK
8	Aluminum	160	1.90	OK
9	Aluminum	160	1.80	OK
10	Aluminum	160	1.70	OK
11	Aluminum	160	1.64	OK
12	Aluminum	160	1.56	OK
13	Brass	70	3.26	OK
14	Brass	70	3.02	OK
15	Brass	70	2.30	OK
16	Aluminum	70	2.00	OK
17	Aluminum	70	2.58	Time from impulse to 1 in. separation
18	Brass	70	3.48	Ditto
19	Brass	70	2.28	OK
20	Brass	70	1.91	OK
21	Brass	70	1.91	OK
22	Aluminum	70	-	Failed, due to faulty seal
23	Aluminum	70	2.12	OK
24	Aluminum	70	1.92	OK
25	Aluminum	70	2.05	OK
26	Aluminum	70	2.16	OK
27	Aluminum	70	1.89	OK
28	Brass	-65	3.12	OK
29	Brass	-65	2.92	OK
30	Brass	-65	-	Failed, due to faulty seal
31	Aluminum	-65	2.38	OK
32	Aluminum	-65	2.43	OK
33	Brass	-65	2.61	OK
34	Brass	-65	2.26	OK
35	Aluminum	-65	2.13	OK
36	Aluminum	-65	2.24	OK
37	Aluminum	-65	2.19	OK
38	Aluminum	-65	2.49	OK
39	Brass	-65	1.64	OK
40	Brass	-65	2.25	OK

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2. Bolts, Release

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